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USE OF FEEDER INSERTS FOR TUNING SHORT-WAVE TRANSMITTING ANTENNAS

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The use of feeder inserts shorter than a quarter wave for tuning short-wave transmitting antennas is discussed. Appropriate formulas are presented. The article also examines the use of feeder inserts for tuning feeders for two wavelengths and for matching a VGD antenna with a feeder line on two multiple wavelengths.

DESIGN OF FEEDER INSERTS

Feeder inserts in the form of so-called quarter-wave transformers find wide use in tuning the feeder lines of short-wave transmitting antennas for traveling-wave operation. Convenient design of such inserts as used at one of the radio enterprises is examined below.

Feeder inserts are sections of feeder line with a characteristic impedance differing from the characteristic impedance of the lines on which they are used as tuning elements. Usually the characteristic impedance W_{ins} of the feeder inserts is lower than the characteristic impedance W_f of the corresponding feeder lines. Connection of a quarter-wave feeder insert is shown in Figure 1.

An extremely convenient design of feeder insert for two-wire feeder lines is shown in Figure 2. The characteristic impedance of such an insert, in the form of a section of four-wire feeder, is calculated from the formula:

$$W = 138 \lg \frac{\sqrt{D_1 + D_2^2}}{D_1} \cdot \frac{2D_2}{d}. \qquad (1)$$

The characteristic impedance is adjusted here by changing the distance D_1. With this design it is possible to lower the characteristic impedance to 300 ohms. Further reduction in characteristic impedance may be obtained by using the designs shown in Figure 3a for two-wire and in Figure 3b for four-wire lines.

The characteristic impedance of the inserts is calculated from the formulas:

$$\left. \begin{aligned} W_{ins} &= \frac{W_1 + W_2}{2}, \\ \text{where} \quad W_1 &= 92 \lg \frac{4D_2 \sqrt{D_2^2 + \left(\frac{D_1}{2}\right)^2} \cdot \sqrt{D_1 + D_2^2}}{4d_1^2} \\ W_2 &= 92 \lg \frac{2D_2 \left[D_2^2 + \left(\frac{D_1}{2}\right)^2\right]}{4d_1^2} \end{aligned} \right| \qquad (2)$$

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and

$$W_{ins.} = \frac{W_1 + W_2}{2},$$

where

$$\left.\begin{aligned} W_1 &= 51 \lg \frac{9D_1 \sqrt{D_2^2 + \left(\frac{D_1}{2}\right)^2} \sqrt{D_2^2 + \left(\frac{2}{3} D_1\right)^2} - \sqrt{D_1^2 + D_2^2}}{4D_1^3}, \\ W_2 &= 64 \lg \frac{27D_1 \left[D_2^2 + \left(\frac{D_1}{3}\right)^2\right] \sqrt{D_2^2 + \left(\frac{2}{3} D_1\right)^2}}{2rD_1^2}. \end{aligned}\right\} \quad (3)$$

Formulas (2) and (3) are derived on the assumption of equal current distribution between wires.

By means of the inserts shown in Figure 3 it is possible to lower the characteristic impedance to 175-200 ohms.

Sometimes the feeder inserts are made of copper tubing and are bound to the feeder wires in the manner shown in Figure 4a for two-wire and in Figure 4b for four-wire lines. The minimum natural traveling-wave coefficient at which the tubular inserts permit obtaining a traveling wave is determined by the diameter of the tubing. If we consider that the use of tubing with a diameter greater than 50 mm is inconvenient, then the value of the minimum natural traveling-wave coefficient for two-wire and four-wire lines is 29 and 32 percent respectively.

TUNING FEEDER LINES BY MEANS OF INSERTS

Present practice in tuning short-wave antennas employs feeder inserts a quarter-wave in length -- quarter-wave transformers. The characteristic impedance of such transformers is determined from the formula:

$$W_t = W_f \sqrt{K_e} \qquad (4)$$

where W_t is the characteristic impedance of the transformer, W_f is the characteristic impedance of the feeder line, K_e is the natural traveling-wave coefficient.

In a number of cases it is convenient to select standard values of characteristic impedance of the feeder line, K_e is the natural traveling-wave coefficient.

In a number of cases it is convenient to select standard values of characteristic impedance for feeder inserts. For example, at one radio enterprise wide use is made of feeder inserts with characteristic impedances of 240 and 220 ohms. Such values of characteristic impedance are obtained if the insert is fastened along the third wire of a four-wire feeder (Figure 3b).

Upon connecting feeder inserts with a characteristic impedance of 240 or 220 ohms, the traveling-wave coefficient is calculated according to formulas (5) and (6), respectively:

$$K = 1.56\ K_e \qquad (5)$$

$$K = 1.86\ K_e \qquad (6)$$

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From these formulas it is seen that traveling-wave coefficient of unity is obtained when $K_e = 64$ and 5. percent, respectively, for each of the above values of characteristic impedance. If it is considered that the minimum value for the traveling-wave coefficient after tuning is 80 percent, then inserts with a characteristic impedance of 240 or 220 ohms may be used within the limits of the following values for Ke, respectively:

$$K_e = 51\text{-}64 \text{ percent, and } K_e = 43\text{-}54 \text{ percent}$$

With values of Ke greater than 64 and 54 percent it is advisable to use short feeder inserts, that is, inserts with a length less than a quarter wave. The length and point of connection of short feeder inserts is calculated from the formulas:

$$\tan ml = \frac{n(K_e - 1)}{\sqrt{(n^2K - 1)(n^2 - K_e)}}, \qquad (7)$$

$$\tan mx = \sqrt{\frac{n^2 - K_e}{Kn^2 - 1}}, \qquad (8)$$

where $n = \frac{W_{ins}}{W_f}$, $m = \frac{360^\circ}{\lambda}$, l is the length of the feeder insert, and x is the distance from the beginning of the feeder insert to the voltage minimum.

In tuning by means of short inserts it is convenient to use the charts shown in Figures 5, 6, 7, and 8, which were plotted from formulas (7) and (8).

In using short feeder inserts for inserts it must be kept in mind that the smaller the ratio W_{ins}/W_f, the shorter the feeder insert at any one traveling-wave coefficient. Hence, from considerations of convenience in installation, in the long-wave portion of the short-wave band (at wavelengths greater than 40 m) it is necessary to lower the characteristic impedance of the feeder inserts in order to decrease their length.

The same enterprise makes wide use of a tuning attachment consisting of an ordinary shorted loop and a feeder insert. This arrangement is shown in Figure 9.

In this case tuning proceeds as follows. The traveling-wave coefficient is measured and the point of voltage minimum is determined. The point of connection and the length of the shorted loop are calculated from the usual formulas. Upon connecting the shorted loop a traveling-wave coefficient of not less than 50-70 percent is obtained, which, upon connecting the appropriate feeder insert, permits traveling-wave operation.

Instead of using a shorted loop, an inductance coil in the form of a helix of bimetallic wire may be connected in parallel with the feeder. The point of connection and the value of inductance are calculated from the following formulas:

$$\tan mx = \frac{1}{K_e}, \qquad (9)$$

$$L = \frac{W_f}{2\pi f} \frac{K}{(1-k)} \text{ henries}, \qquad (10)$$

where f is the operating frequency.

Operational experience shows that tuning by means of feeder inserts has the following advantages:

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1. Excellent coincidence of calculated values and measured values. Upon connecting the insert the traveling-wave coefficient differs from its calculated value by not more than 3-5 percent.

2. Stability of tuning. The value of the traveling-wave coefficient is maintained over a long period (over six months), which cannot be said of tuning by means of shorted loops.

3. In using the antenna over the range of a single broadcast band the traveling-wave coefficient does not decrease by more than 15-25 percent.

A feeder line may easily be tuned to two wavelengths by means of a feeder insert; for example, for operation in two adjacent broadcast bands. For this purpose several voltage minimums (four or five) are located on each wavelength and points are chosen at which, as closely as possible, these voltage minimums coincide. Appropriate feeder inserts are connected at these points, the length being the average for both wavelengths.

Example

It is required to tune a feeder line with a characteristic impedance $W_f = 300$ ohms to wavelengths of 20 and 25 meters. It is known that Ke at both wavelengths is 60 percent.

For the purpose of tuning we select an insert with a characteristic impedance of 240 ohms and a length of 5 meters, and connect it to the points of coincidence of the minimums. Then for the 20-m wavelength we obtain $K = 1.56 \times 0.6 \times 100\% \approx 93\%$ and for the 25-m wavelength $K = 84\%$. (Calculation for 25 meters is performed with the use of a circular diagram. For an example, see G. Z. Ayzenberg, Antenny dlya magistral'nykh korotkovolnovykh radiosvyazey [Antennas for Principal Short-Wave Radio Communications], Svyaz'izdat, 1948.)

In conclusion we will discuss the tuning of a VGD antenna by means of a feeder insert for two multiple wavelengths. The characteristic impedance W_d of the dipole in this case is chosen at 350 ohms. This insures matching of the dipole with a feeder line having a characteristic impedance of 600 ohms with the length of one arm of the dipole $l = \frac{\lambda short}{2}$ (λ short is the shorter of the two multiple wavelengths). In effect, in this case the input resistance of the dipole is determined from the formula

$$R_{in} = \frac{W_d^2}{R_\Sigma} = \frac{350^2}{200} = 600 \text{ ohms}$$

where $W_d = 350$ ohms is the characteristic impedance of the dipole, $R_\Sigma = 200$ ohms is the radiation resistance of the dipole with the half length λ.

Thus, on the shorter wavelength λ short $= 2l$ matching is obtained without the use of a feeder insert. On the longer wavelength λ long $= 4l$ the input resistance of the dipole is 73 ohms. In order to match it with a feeder line having a characteristic impedance of 600 ohms, a quarter-wave insert with a characteristic impedance of 220 ohms connected directly between the input of the dipole and the feeder line is entirely satisfactory.

The traveling-wave coefficient after connection of the insert is

$$K = \frac{R_{in}}{W_f} \left(\frac{W_f}{W_{ins}}\right)^2 \times 100\% = \frac{73}{600} \left(\frac{600}{220}\right)^2 100\% = 91\%$$

It is evident that at the shorter wavelength the feeder insert will be a half-wave section and will not disturb the natural matching between the dipole and the feeder.

There is no doubt that the above information does not exhaust all the possibilities for extensive use of feeder inserts in tuning short-wave antennas.

FIGURES

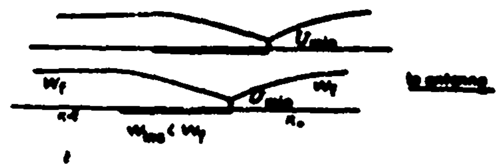

Figure 1

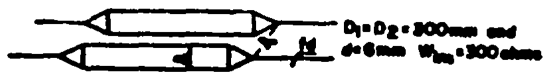

Figure 2

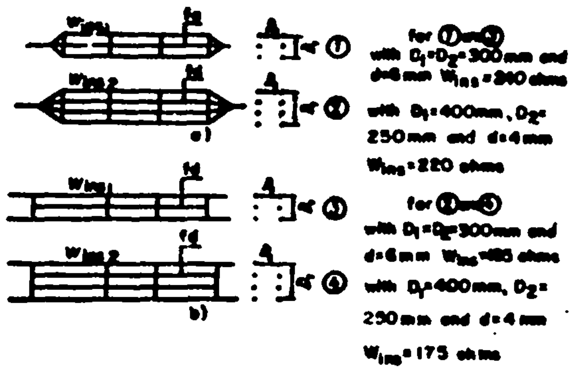

Figure 3

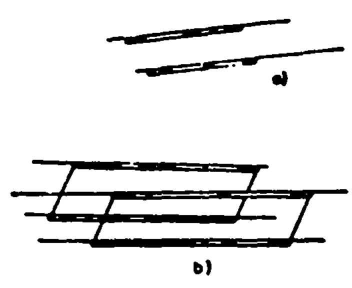

Figure 4

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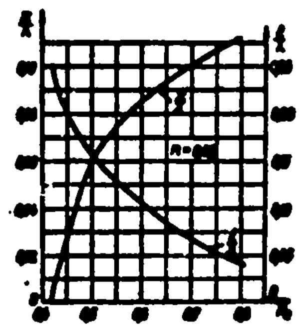

Figure 5

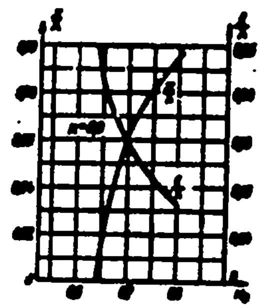

Figure 6

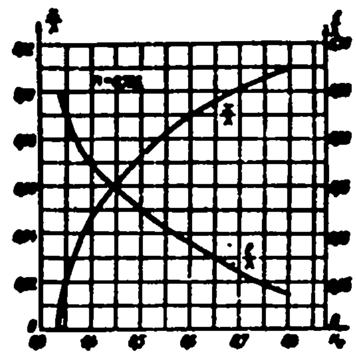

Figure 7

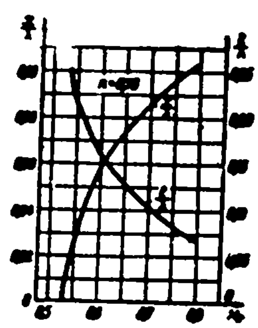

Figure 8

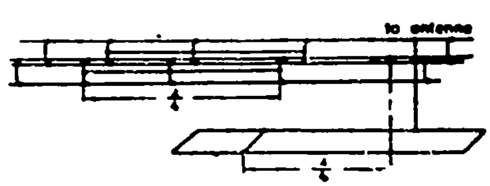

Figure 9

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